Babcock & Wilcox

Power Generation Group

P.O. Box 1260, Lynchburg, Va. 24505
Telephone: (804) 384-5111

November 2, 1979

Mr. Darrell G. Eisenhut
Deputy Director
Division of Operating Reactors
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Eisenhut:

On November 1, 1979, the NRC held a meeting with all of the fuel vendors and many of the operating plant utilities to discuss the impact of a potential revision of the cladding rupture models used in LOCA evaluations. B&W participated in that meeting and responded fully to your inquiries. This letter provides a written response to three questions raised by the NRC staff in the meeting.

Question #1

Do the fuel rupture and swelling models meet the requirements of Appendix K of 10 CFR 50?

Response

The B&W evaluation model, as approved by the NRC staff, has been reviewed against the criteria of Appendix K. The B&W evaluation model includes provisions which are conservatively implemented relative to the potential effects of clad swelling and rupture on a LOCA evaluation. The B&W approach meets and exceeds the requirements of Appendix K, 10 CRF 50.46.

Appendix K in Section I.B., "Swelling and Rupture of the Cladding and Fuel Rod Thermal Parameters," states:

> "Each evaluation model shall include a provision for predicting cladding swelling and rupture from consideration of the axial temperature distribution of the cladding and from the difference in pressure between the inside and outside of the cladding, both as functions of time. To be acceptable the swelling and rupture calculations shall be based on applicable data in such a way that the degree of swelling and incidence of rupture are not underestimated. The degree of swelling and rupture shall be taken into account in calculations of gap conductance, cladding oxidation and embrittlement, and hydrogen generation."

6002
S
111

1296 339

7911080318

The underlining has been added for emphasis. The B&W evaluation model is based on applicable data* and was approved by the NRC in 1976. The model is documented in BAW-10104A, "B&W's ECCS Evaluation Model", report.

The model works in the following way:

1. A stress versus rupture temperature curve is employed to predict the occurrence of rupture.

2. A rupture temperature versus percent strain curve (or equivalent variable) is used to predict local rod deformation and applied over a 3" segment for determination of cladding temperature.

3. The local deformation determined from step 2 is treated as co-planar blockage across a fuel assembly to establish the coolant channel flow area reduction.

4. In conjunction with the reduced flow area, a one velocity head flow resistance drop is added to the flow channel resistance to predict post-rupture flow.

Adherence to Appendix K in the approved B&W evaluation model is provided as follows:

1. B&W's existing correlations have been based on data which have been determined to be applicable to the B&W design by engineering evaluation.

2. The rupture criteria curve (Figure 1) over-predicts the incidence of rupture because it uses temperatures for rupture that are low relative to available data.

3. The treatment of the local percent strain curve is an envelope over the applicable data set. The use of the maximum strain over a full 3" segment of the cladding over-predicts the cladding surface area for metal-water reaction and thus over-predicts the reaction heating.

4. The assumption of co-planar blockage is made in determining flow blockage up to an assembly blockage of 70%. If the co-planar assumotion would create an assembly blockage greater than 70%, the blockage is limited to 70%. These assumptions over-predict the amount of flow channel blockage.

1296 340

---

* Applicable data refers to the available data set as of 1976 which was carefully evaluated for applicability to B&W plant LOCA analyses.

5. It is expected that the one velocity head loss factor can, in addition, be shown to be conservative by a factor of approximately three on flow resistance.

6. The gap conductance, after rupture, is dominated by radiant heat transfer and is, therefore, independent of the amount of strain at the ruptured location.

Comparison of B&W curves to the NRC curves is shown in Figures 1, 2, and 3. B&W stated in the November 1, 1979, meeting that we have not yet had the opportunity to assess the applicability of the NRC data to our model and assure the quality of the data. However, we believe that if the new data is assumed to be applicable to the B&W evaluation model, it is the judgment of our technical experts that compliance with the requirements of Appendix K would be demonstrated.

For the fast ramp NRC curves, the applicable curves for large break LOCA, the B&W model over-predicts both the incidence of rupture and the amount of flow channel blockage. The percent strain comparison shows that our approach predicts lower strain for local effects than the NRC envelope or upper bound curve. However, the NRC curve has been constructed to only account for the maximum strain at the point of rupture and is very conservative when applied over the entire rupture length. The B&W strain curve, which is applied over a three inch segment, results in swelling in agreement with the applicable test data and therefore does not under-predict the degree of swelling.

Question #2

Do the plants meet the 2200^{o}F criterion of 10 CFR 50.46?

Response

As discussed above, the B&W evaluation model meets the requirements of Appendix K. The evaluation model has been employed for all B&W operating plants and adherence to the criteria of 10 CFR 50.46 is demonstrated. Therefore, no B&W plant will exceed a peak cladding temperature of 2200^{o}F, nor the other criteria imposed by 10 CFR 50.46. However, the NRC presented curves during the November 1st meeting which differed in some aspects from those used by B&W. Without accepting the validity of the NRC curves, the remainder of this answer will establish the potential impact of the NRC curves as if they were incorporated directly into the B&W evaluation model.

The considerations of the curves' impact is broken into two parts: (1) the impact on large break evaluations and (2) the impact on small break evaluations. We will first deal with large break LOCA's.

For large breaks, the clad heating rates are predicted to lie between 15°C/s and 25°C/s at the time of rupture. The NRC fast ramp curve would therefore be appropriate for comparison to that utilized in the B&W evaluation model. As shown in Figure 2, the B&W curve lies below the NRC curve and would thus predict a higher incidence of clad rupture.

Excepting the peak in the NRC curve at 1.6 KPSI, the NRC blockage curve is either in agreement with the B&W curve, at high stress, or below the B&W curve at moderate or low stress, Figure 3. Thus, the NRC curve would predict less reduction in flow and greater cool-ability after rupture. This statement applies during blowdown. During reflooding, the FLECHT data has been judged to predict heat transfer conservatively for blocked or unblocked cores so long as flooding rates are above 1 in/sec. Statements to this effect are contained in Appendix K of 10 CFR 50.46. B&W's flooding rates are above 1 in/sec for all evaluations, well past the time of peak cladding temperatures. For some evaluations where the peak occurs high in the core, a lower than one in/sec flooding rate can occur for a short time after the time of peak cladding temperature and before core quench. B&W uses a conservative steam cooling model, including blockage effects at this time. As mentioned, the degree of blockage is over-predicted because the blockage occurs prior to peak cladding temperature and, therefore, the present model is conservative.

The local burst strain curve of the new NRC data is above the curve used by B&W in its evaluation model (Figure 2). These curves are derived from measurements of maximum local strain at the point of rupture. In B&W's model, the strain from this curve is applied uniformly for a full three inches along the fuel pin length. Realistically, this maximum strain probably exists over no more than about one inch axially, with reduced strain elsewhere. It is our judgment that the higher strain values of the NRC curve, if used with a more realistic axial model of the rupture effect, would predict cladding swell and exposed surface area not significantly different from the existing B&W evaluation model.

Should the higher burst strain curve of Figure 2 actually result in greater total clad dislocation, it is not likely to increase peak clad temperature significantly. Excess strain would manifest itself mainly in higher heating rates due to metal-water reaction, as discussed below:

1. The gap would increase. Because gap heat transfer is dominated by radiant effects, little change in heat transfer would occur.

2. More surface area would be exposed for metal-water reaction, thus slightly higher heat rates and more oxidation would be calculated. The impact of the higher heating rates is inconsequential because:

   a. B&W predicts rupture to occur during blowdown when coolant is available to remove the heat.

b. When rupture occurs the cladding in the vicinity of the rupture cools due to the reduction in gap heat transfer.

c. The peak cladding temperature generally does not occur at a ruptured location on the fuel.

d. For those few times when the ruptured location sets the peak cladding temperature, the driver for cladding temperature is mainly fuel pellet energy as opposed to metal-water reaction, and, thus, little impact would result. In these calculations, which form the basis for LOCA limits at the 2- and 4-foot core heights, some minor impact on peak clad temperature might occur. Our judgment is that this will not cause an increase in peak temperature past 2200°F.

The rupture strain curve used in the B&W evaluation model is concluded to be approximately equivalent in application to the NRC peak strain curve were the NRC curve to be applied realistically with strain determined as a function of axial distance from the rupture. It is further concluded, however, that application of the higher NRC peak strain curve over the axial length assumed in the B&W evaluation model would not result in peak cladding temperatures in excess of 2200°F.

For small breaks, the NRC slow ramp data would be appropriate. B&W small break analysis does not generally predict any cladding heatup for small breaks because no core uncovery is predicted. For a very specific set of break sizes and under full Appendix K assumptions, a small amount of core uncovery and resultant clad temperature excursion has been predicted. For the worst case, the peak cladding temperature is 590°C and the stress is below 8.4 KPSI. This temperature and stress combination is approximately 150°C below the 0°C/s rupture stress NRC curve. Therefore, no rupture or swelling will occur and the use of the NRC curves would have no impact on our small break predictions.

The above comments apply to all operating B&W plants regardless of design because the implications drawn are taken from the evaluation model which is applied uniformly regardless of design.

Question #3

If the response to Question #2 is "no", define proposed interim actions the affected plants might take.

Response

In view of B&W's response to Question #2, this question is not applicable to plants utilizing the B&W NSSS.

In conclusion, B&W believes

1. that its present model is in compliance with 10 CFR 50.46 and Appendix K,

2. that a uniform inclusion of the NRC proposed rupture and strain curves would have no impact on our evaluation of LOCA, and

3. that even the most conservative inclusion of the NRC curves would have little impact and not result in predictions of cladding temperatures in excess of 2200°F.

In view of the above, we believe that the new data does not change the conclusions of the previously completed safety analyses for the operating plants utilizing the B&W NSSS.

Very truly yours,

James H. Taylor
Manager, Licensing
Nuclear Power Generation Division

JHT:nw

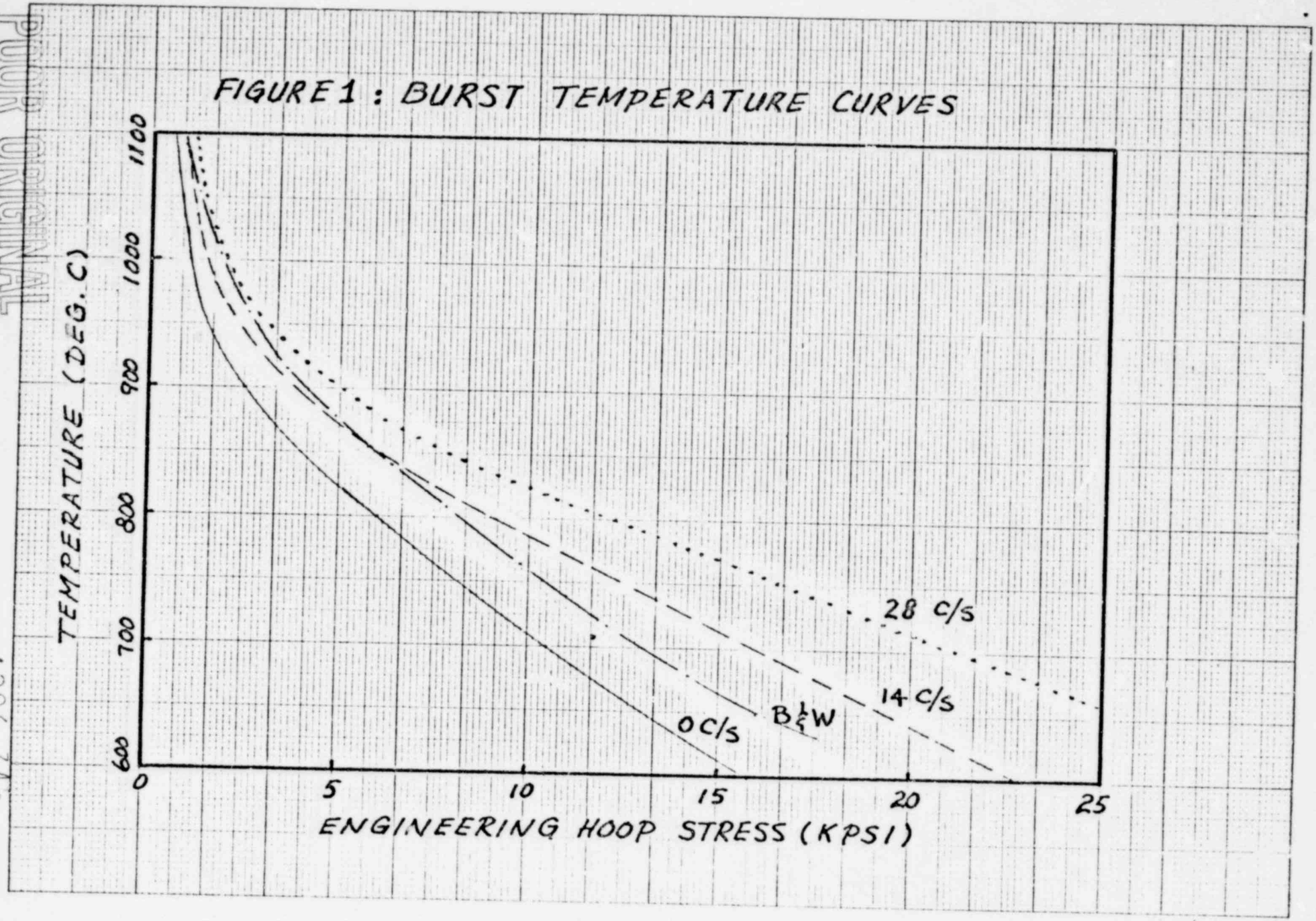
Attachments

cc: Mr. R. B. Borsum

K&E 20 X 20 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

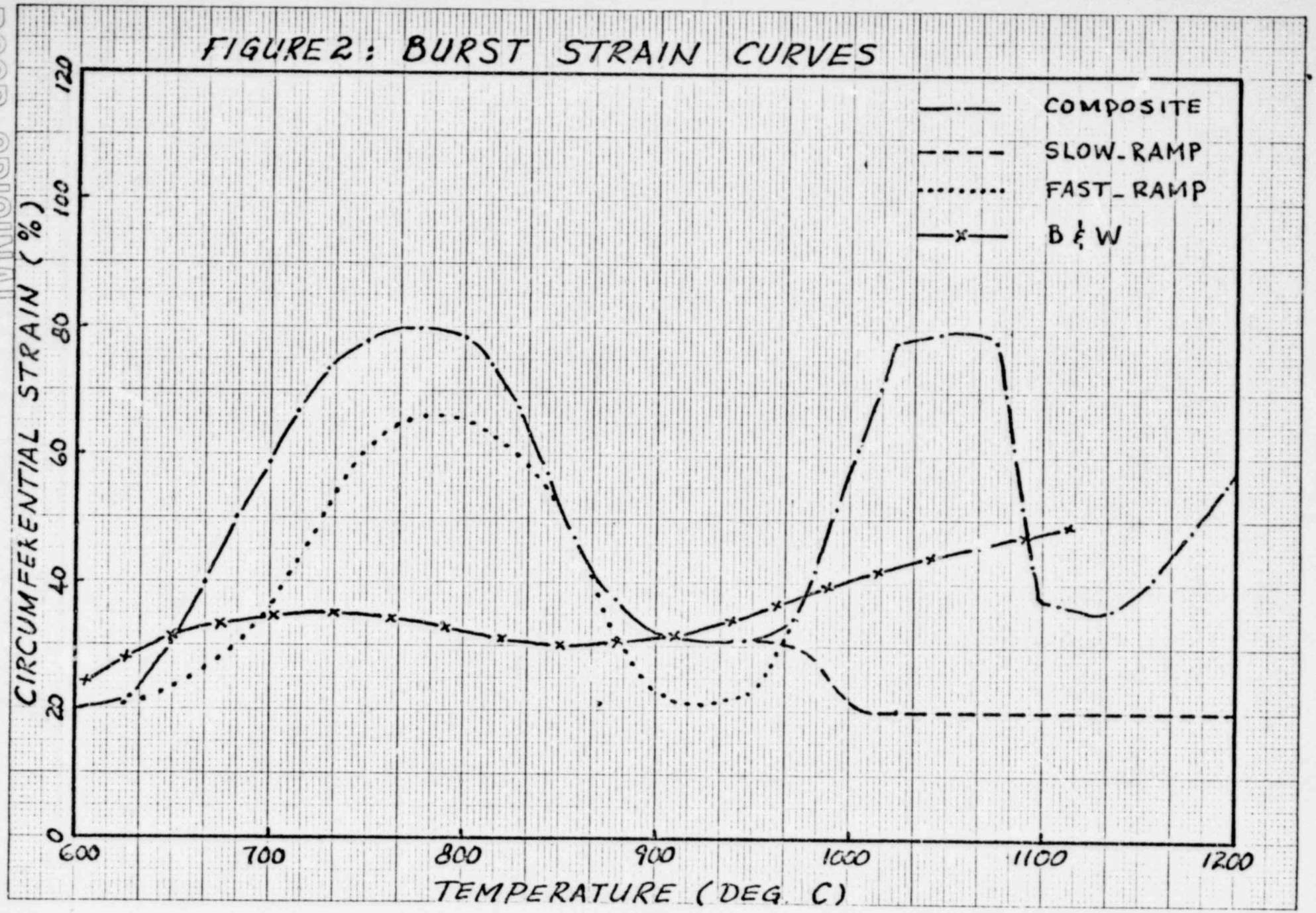
POOR ORIGINAL

FIGURE 1 : BURST TEMPERATURE CURVES



1296 345

POOR ORIGINAL

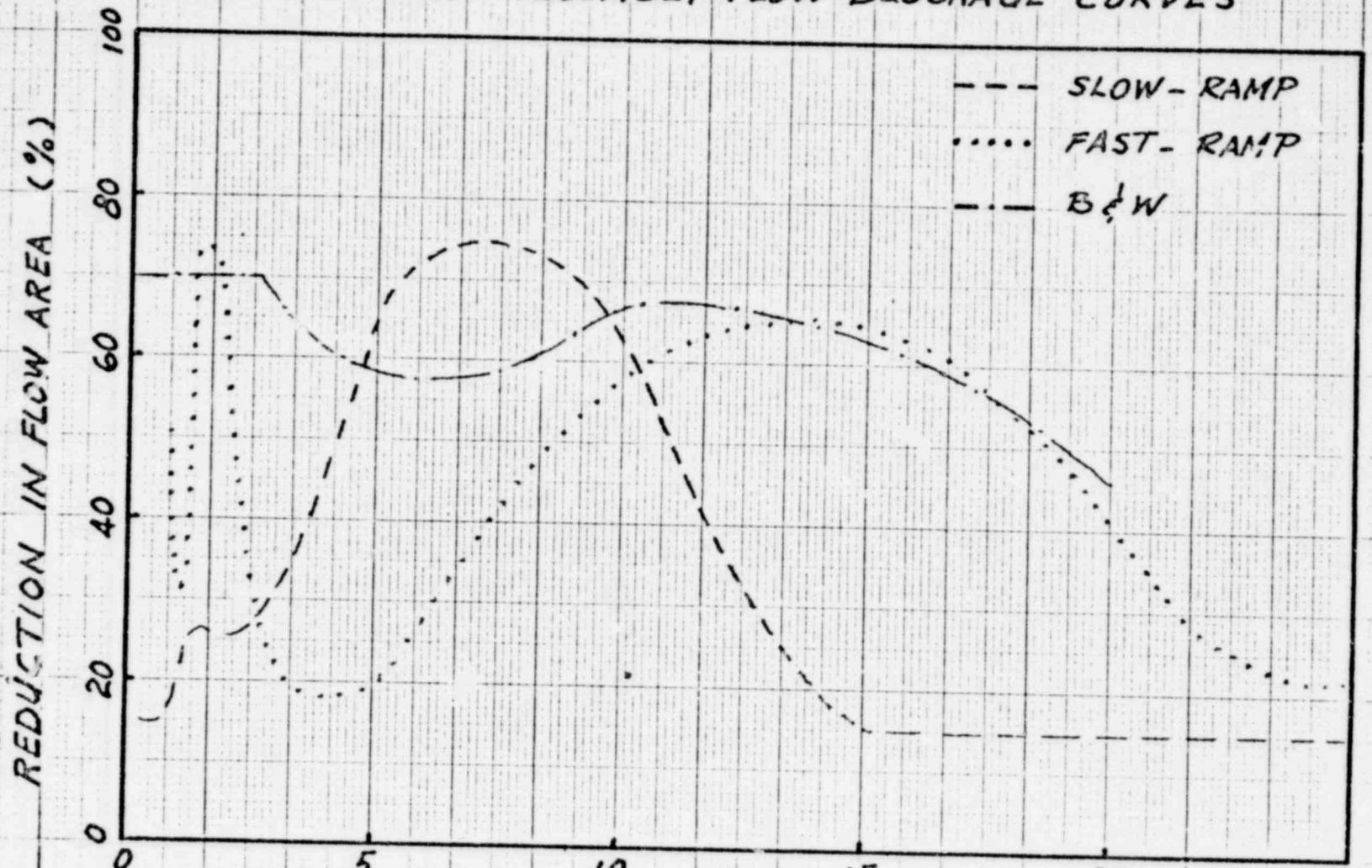


1296 346

20 X 20 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

POOR ORIGINAL

FIGURE 3: PWR ASSEMBLY FLOW BLOCKAGE CURVES



QIP. 3-11 11-2-79